



Challenges in risk assessment Insidious erosion of safety margins over time

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Presentation on NSOAF safety conference 2010

COWI was requested by the Danish Energy Agency to submit a presentation on the annual North Sea Offshore Authorities Forum (NSOAF) upstream safety conference in Aberdeen on 23 November 2010. The subject was Challenges in risk assessment, and Frank Hedlund used a case from the aviation industry to show how safety margins are able to drift towards nil over a span of years, if they are not carefully controlled.

There is much evidence that safety margins may be eroded bit by bit, often without anyone noticing, eventually leading to a serious mishap. After an accident has taken place, it is often all too easy to point out previous deviations and near-misses, which, with the benefit of hindsight, clearly demonstrate that vulnerabilities existed and evidently were harbingers of the accident to come, but which were either ignored or considered insignificant at the time.

This is not just second-guessing. These are the challenges of modern safety management to pro-actively identify and recognize at an early stage the events and deviations that convey information about safety performance dysfunction.

Loss of control and impact with the Pacific Ocean of Alaska Airlines flight 261 McDonnell Douglas MD-83, N963AS, about 2.7 miles north of Anacapa Island, California. 31 January, 2000:

In summary, the root cause of Flight 261's tragic end was not the failure of the jackscrew assembly, but rather the **cumulative and insidious effect of both economic and organizational pressures acting on all levels** of Alaska Airline's organizational hierarchy.

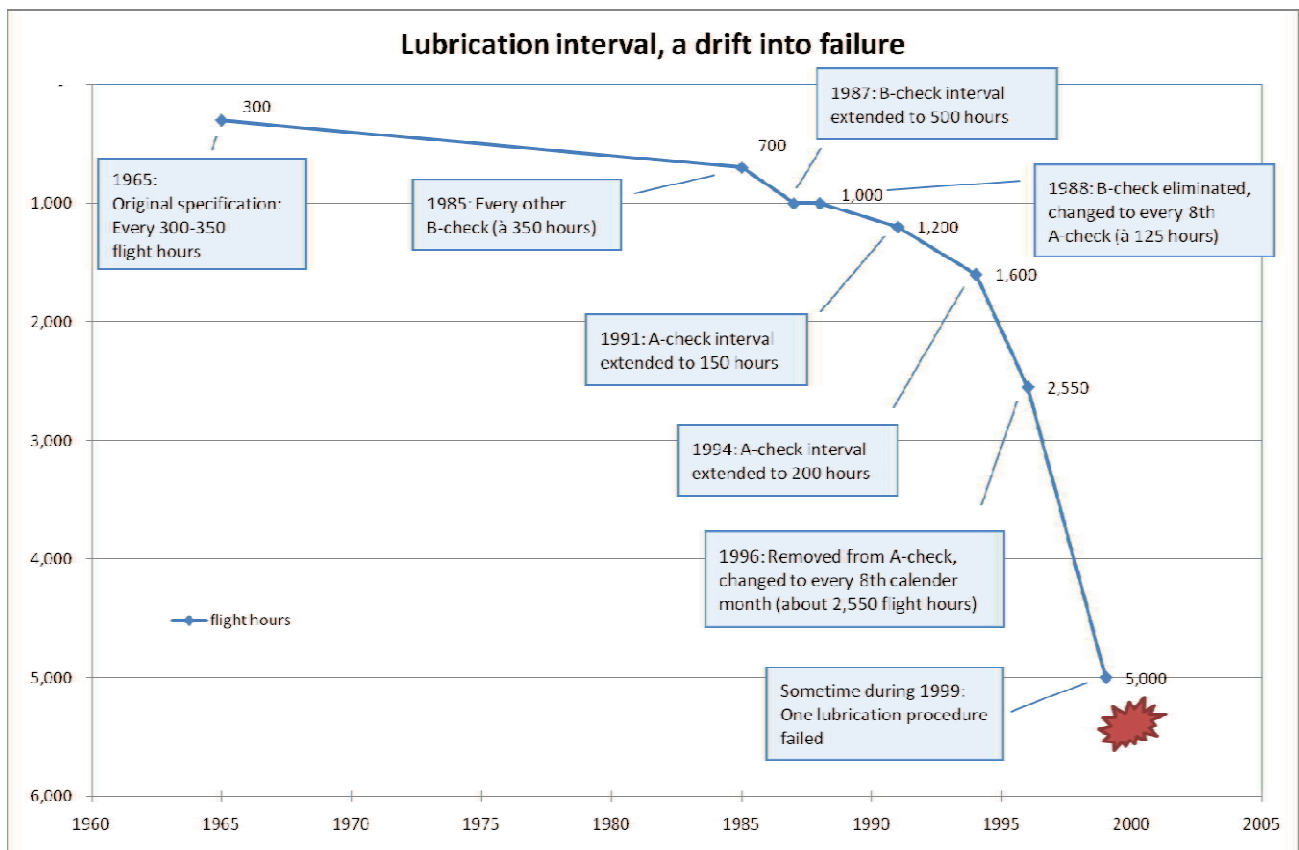
The immediate technical cause for this crash relates to inadequate lubrication of a critical component in the tail section of the jet. The graph below shows how processes of drift hollowed out the margins of safety originally engineered into the system, to the extreme point where a single failed lubrication procedure, in this case caused by a careless mechanic, would lead to catastrophic failure.

Multiple organizations were involved and all changes were concurred by the aircraft manufacturer and the regulatory oversight agency. What is particularly notable in this case is that while each of the changes, assessed individually, would be insignificant, the sum of the many steps, all in the wrong direction, turned out to be fatal.

In what is typical for accidents, no one saw it coming, and it is only with the benefit of hindsight that events and deviations, which at the time of their occurrence were dismissed as insignificant, after the accident were seen as obvious and unmistakable accident precursors that could have alerted to the fact that margins of safety were wearing thin.

While the fundamental idea that near-miss investigation may serve as a tool to predict future serious mishaps has been known for at least 40 years and theoretically builds on work by Heinrich in the 1930s, the

concept, in a modified version adapted to present day conditions, is still an important tool in the palette of safety management interventions available to decision makers and safety professionals.



The presentation from the NSOAF upstream safety conference 2010 is enclosed overleaf.

The presentation was also given at a meeting arranged by Mærsk Olie og Gas A/S in Copenhagen on 10 May 2010.



Challenges in risk assessment

Insidious erosion of safety margins over time

**NSOAF - Second international safety conference in the
upstream oil & gas industry,**

Aberdeen, 22nd -23rd November 2010

Dr. Frank Hedlund
COWI, Denmark

Theme: Challenges (and pitfalls) in Risk Assessment

- HSE Research report RR151.
- Additional challenge: that of **incrementalism** leading to **drift**
- The sum of many small steps, all in the wrong direction. While each step is insignificant when viewed in isolation, combined they accumulate to reduce safety over time in a stealthy manner oblivious to all involved actors, operators and oversight agencies alike



Good practice and pitfalls in risk assessment

Prepared by **the Health & Safety Laboratory**
for the Health and Safety Executive 2003

Alaska Airlines flight 261

Loss of Control and Impact with Pacific
Ocean Alaska Airlines Flight 261
McDonnell Douglas MD-83, N963AS
About 2.7 Miles North of
Anacapa Island, California
January 31, 2000

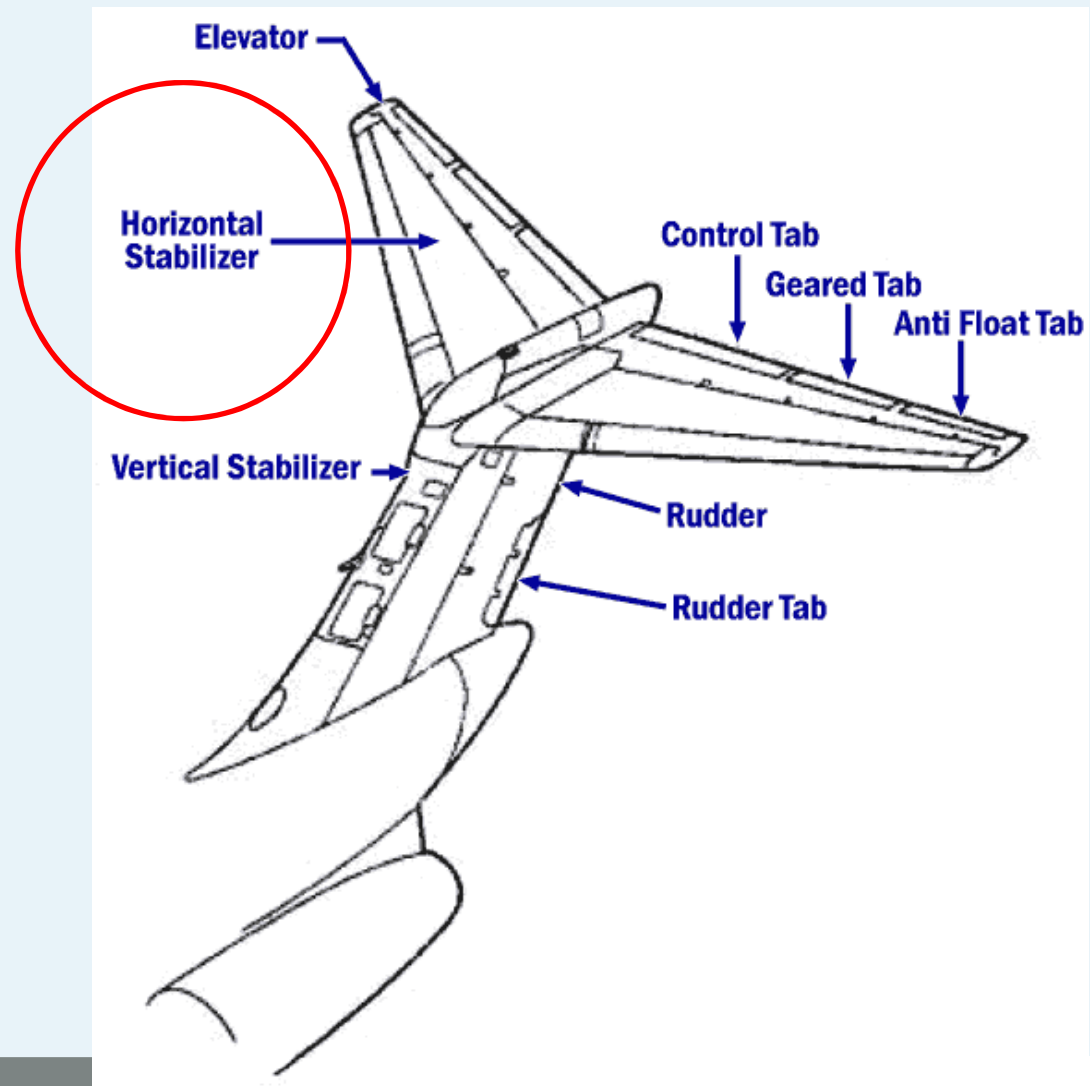
Purpose

- To examine this crash, with a focus not on the technical failure of the mechanical components, but on the roles played by the human influence from upper management of Alaska Airlines and the FAA down to the culture of the maintenance crew
- In summary, the root cause of Flight 261's tragic end was not the failure of the jackscrew assembly, but rather the **cumulative and insidious effect of both economic and organizational pressures acting on all levels** of Alaska Airline's organizational hierarchy.
- The true value of the lessons learned from Flight 261 lies in the importance of taking a comprehensive, systems perspective of organizational risks.

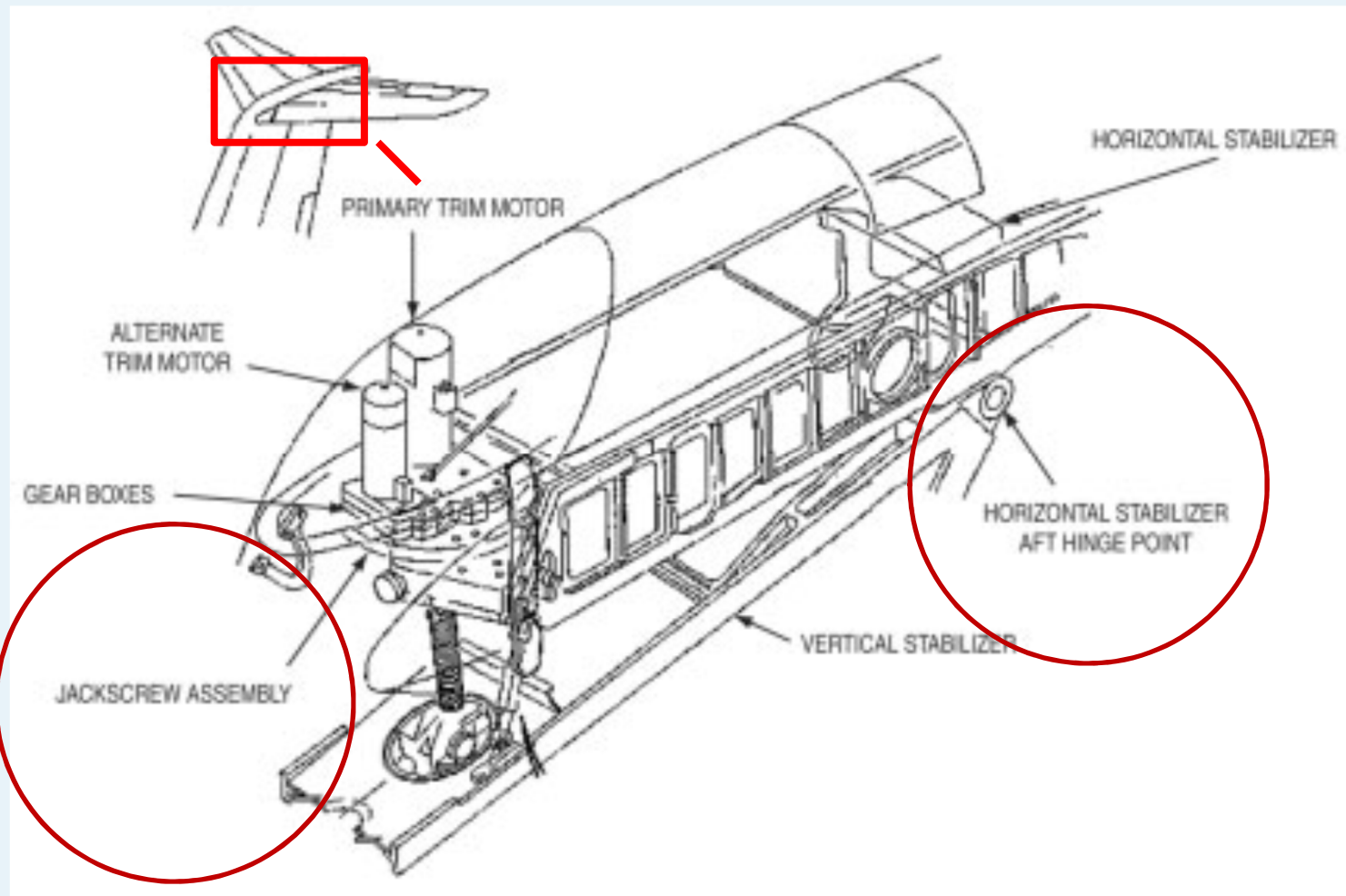
Type of aircraft in flight.

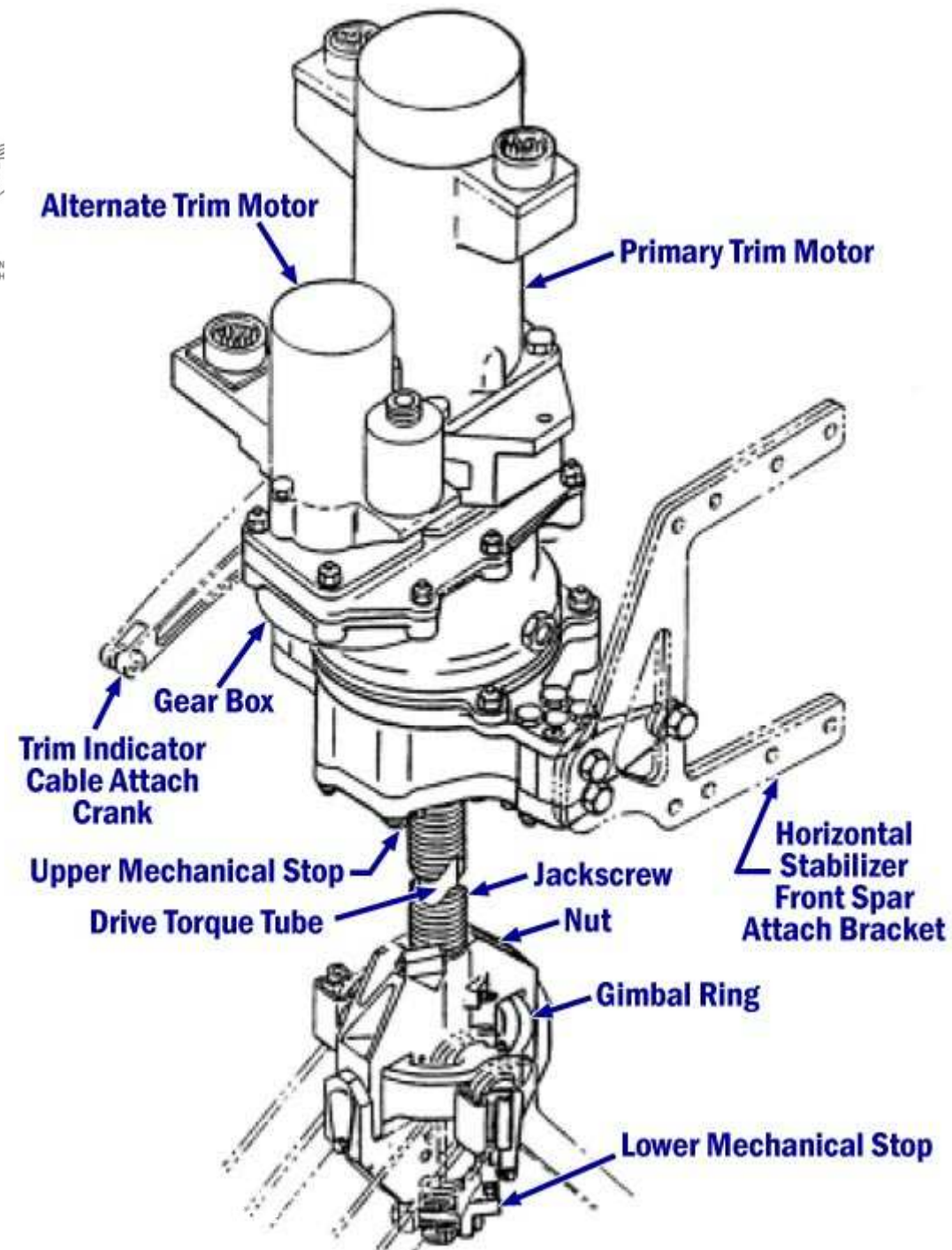
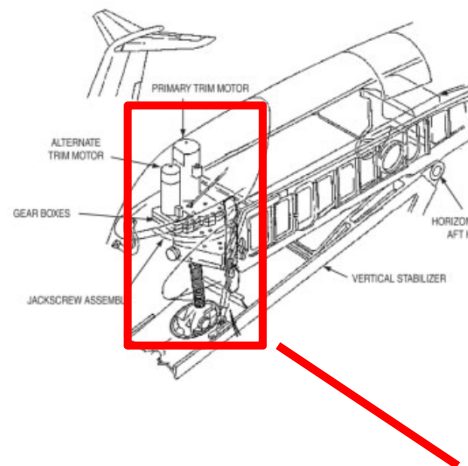


Tail wing – control surfaces



Jackscrew assembly within the horizontal and vertical stabilizers





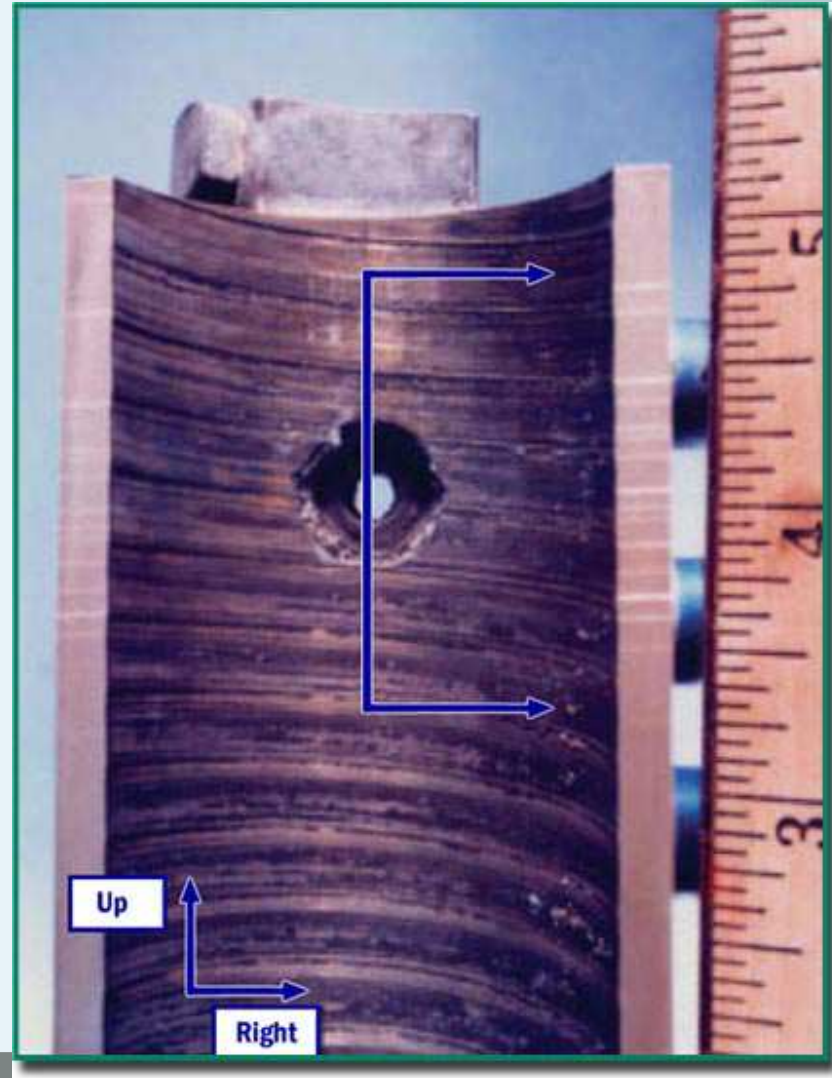
Acme nut



Gimbal nut from Alaska Airlines flight 261, shown below as attached to front spar of stabilizer from the aircraft's tail, and in close-up

Acme nut severely worn

Approximately 90 percent of the thread thickness had worn away before the remainder of the threads sheared off.



Jackscrew with metal shavings

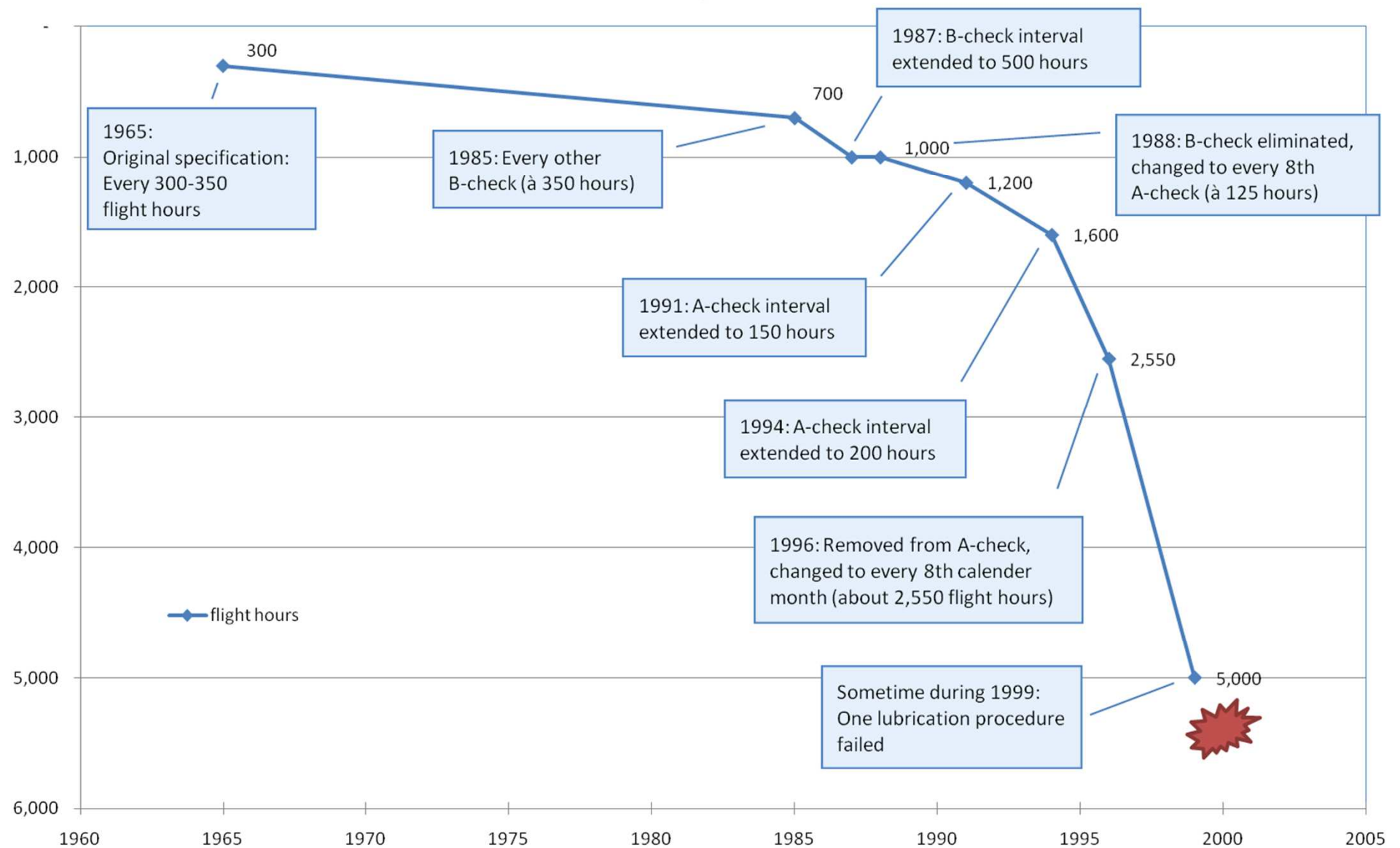


Jackscrew from horizontal stabilizer of Alaska Airlines flight 261, recovered from the wreckage

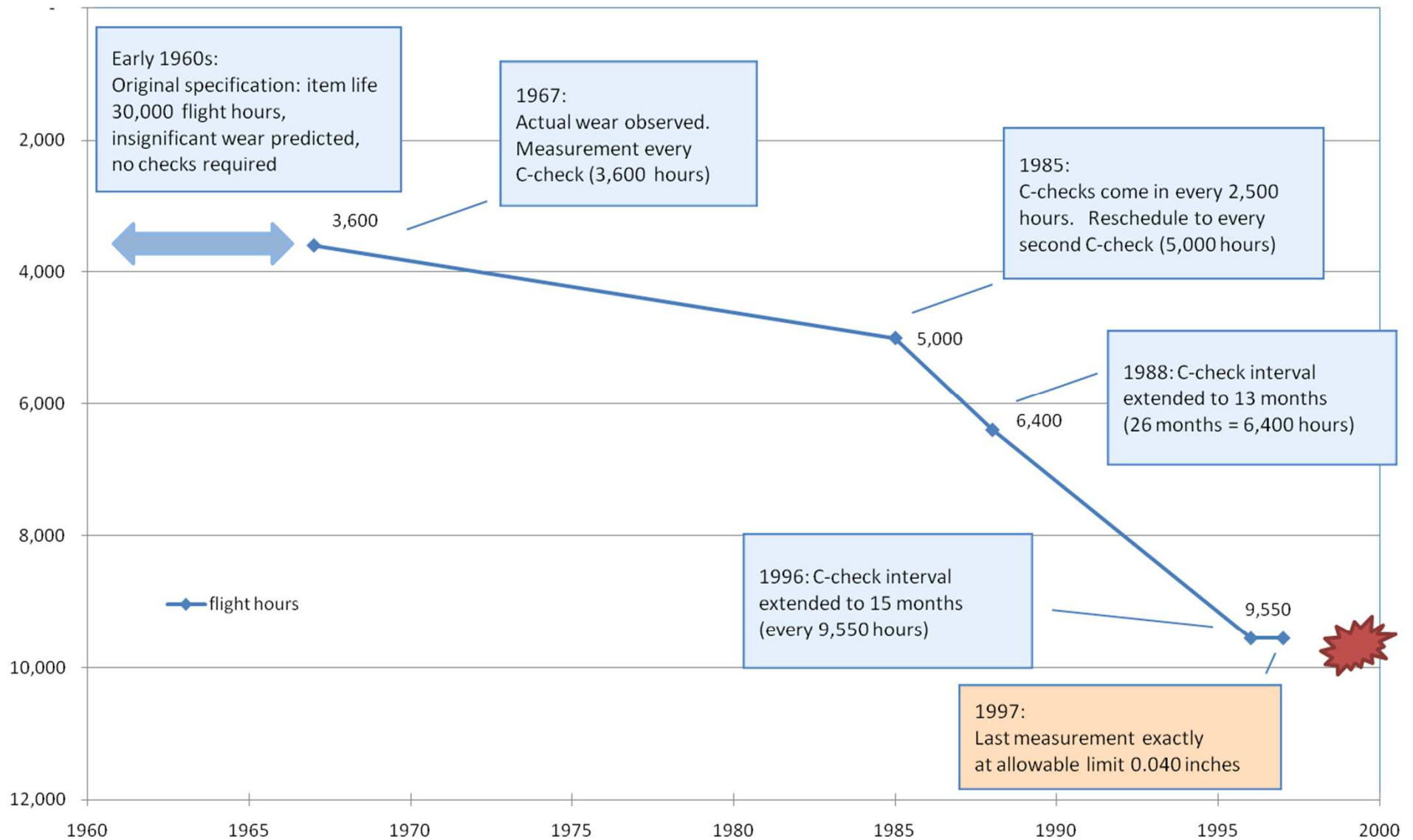
Cause of excessive wear: Lubrication failure

- Preventive measure:
- Alaska Airlines, with FAA approval, increased the **lubrication interval** from 500 flight hours to every eight calendar months. (wear is a function of aircraft usage, not calendar time). (decreases the tolerance for missed or inadequate lubrication).
- Risk control measure:
- The **thread wear check** to determine the airworthiness of the jackscrew assembly was required at every other C check. However, the C check interval was extended.

Lubrication interval, a drift into failure



Thread wear check interval, a drift into failure



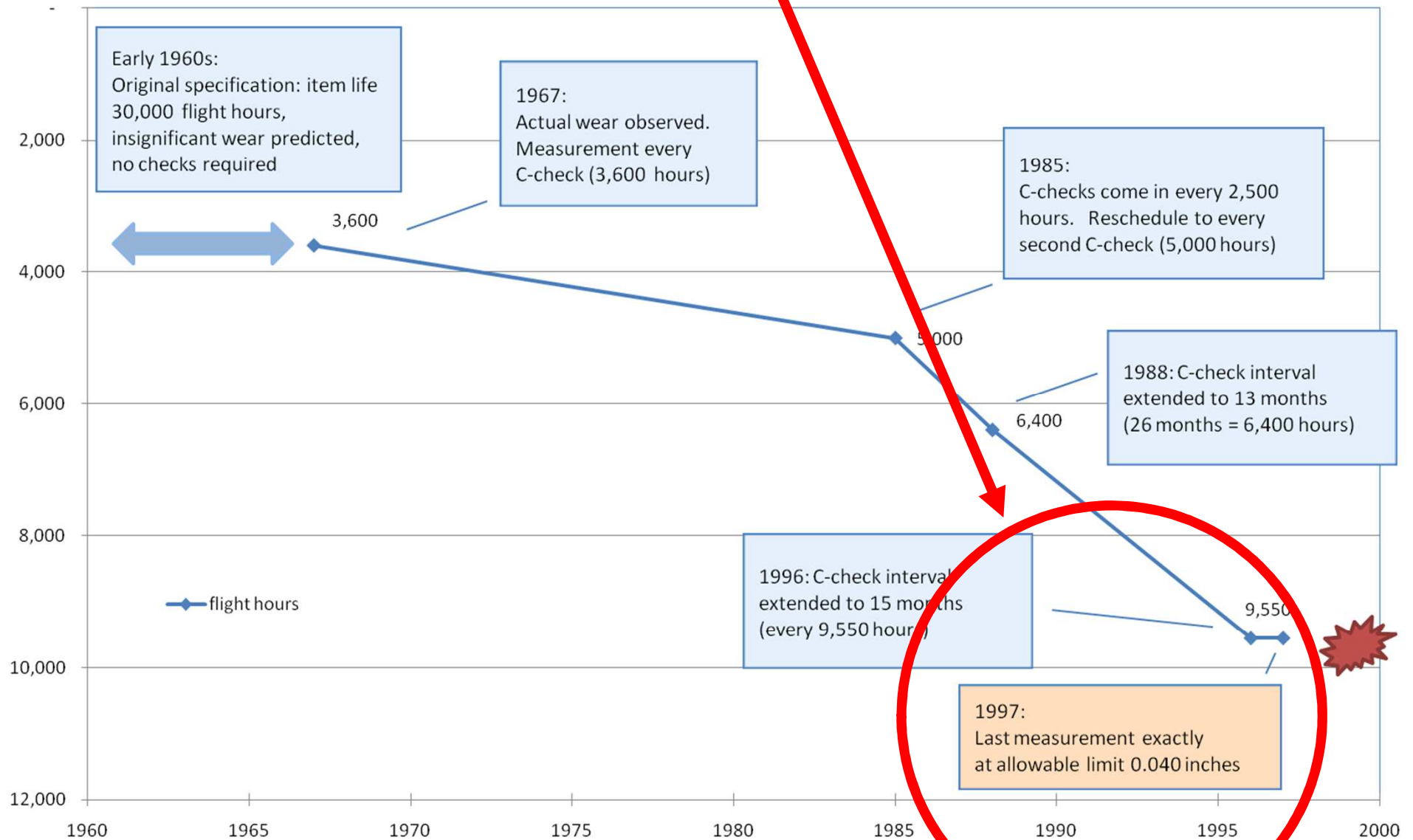
The extensions

- The extensions were hardly the product of manufacturer recommendations alone, if at all.
- A much more complex and constantly evolving web of committees with representatives from regulators, manufacturers, subcontractors, and operators was at play.
- All extensions have (presumably) undergone a successful risk assessment (pitfall)

Characteristics of drift

- Each extension made local sense, and was only an increment away from the previously established norm.
- No rules were violated, no laws broken.
- The regulator concurred with the changes. These were normal people doing normal work
- Maintenance technicians were never required to record or keep track of thread-wear measurements. The manufacturer had not expressed interest in seeing these numbers or the slow unfavorable trend they might have revealed.
- If there was a drift, no institutional or organizational memory would know it.

The last thread wear measurement



Accident airplane's last thread wear check - 1997

Zone/Area 41	<i>Alpha Airline</i> MIG-4 NON-ROUTINE WORK CARD	Generating Item 24627000	No. of Men 1	Shift 3																		
Work Order No. 02525	Trap No. 71	Date 9-27-97	Station OK	Log. M. Hvy 5.0																		
IRF NO 4236374	A/C NO. 963	FLY or CHECK 5C	OPERATING EMPLOYEE 165451	ASA CODE 274AD																		
Discrepancy:																						
HORIZONTAL STAB - ACME SCREW AND NUT HAS MAXIMUM ALLOWABLE END PLAY LIMIT (.040 IN.)																						
Planned Action: - Replace nut and perform E.O. 8-55-10-01 R# 9/30/97 Re-evaluate test per W.C. 24627000																						
Authorized by: <i>RS 40462</i>																						
IRO 2740	EMPLOYEE NO. 52471	Enter "Y" for correction or code for delimit (obtain code from SEA M.G.) Y OK 30 SEA Partial work on back <input type="checkbox"/>																				
Corrective Action: Rechecked Acme screw & nut end play per W.C. 24627000. Found end play to be within limits .033 for step 11 and .001 for step 12. Rechecked five times with same result.																						
Corrected by: <i>Ron Gill</i> Reviewed by: <i>RS 59451</i>																						
Final Inspection Due Date: 14983																						
Enter rotatable change information below.																						
<table border="1"> <tr> <td>1. TRACKING NO. ON</td> <td>ASA S/N OFF</td> <td>2. TRACKING NO. ON</td> <td>ASA S/N OFF</td> <td>3. TRACKING NO. ON</td> <td>ASA S/N OFF</td> </tr> <tr> <td colspan="6">Were rotatables changed due to: (c) Convenience <input type="checkbox"/> (s) Scheduled <input type="checkbox"/> (u) Unscheduled <input type="checkbox"/></td> </tr> <tr> <td colspan="6">Check if ANETC entry required <input type="checkbox"/></td> </tr> </table>					1. TRACKING NO. ON	ASA S/N OFF	2. TRACKING NO. ON	ASA S/N OFF	3. TRACKING NO. ON	ASA S/N OFF	Were rotatables changed due to: (c) Convenience <input type="checkbox"/> (s) Scheduled <input type="checkbox"/> (u) Unscheduled <input type="checkbox"/>						Check if ANETC entry required <input type="checkbox"/>					
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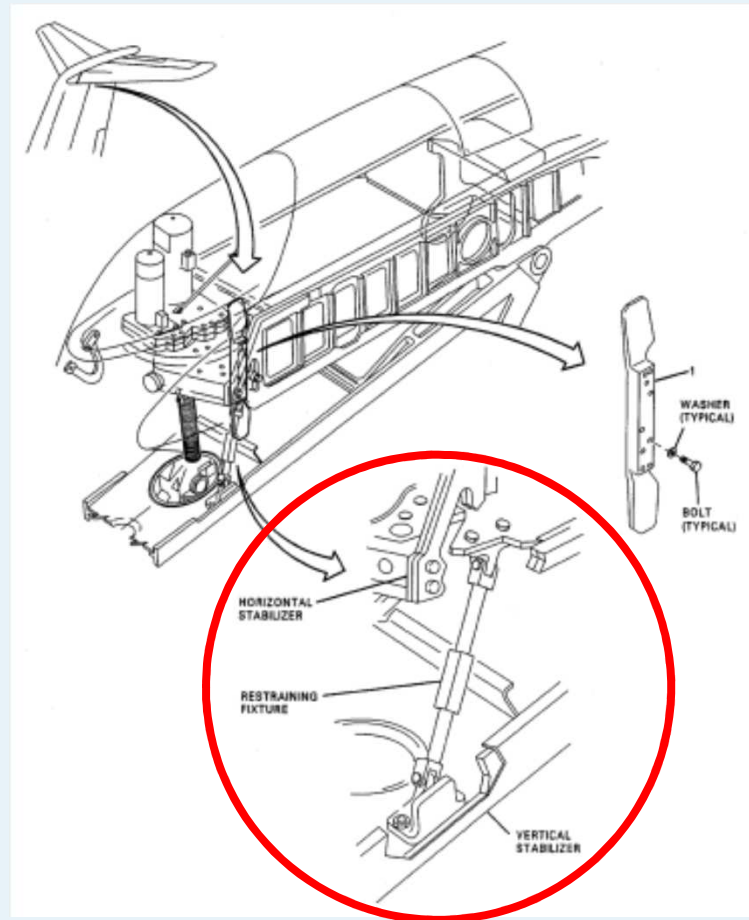
CONFIDENTIAL

"Horizontal Stab - acme screw and nut has maximum allowable end play limit (.040 in.)." The planned action box, which was filled out by the day-shift lead mechanic and inspector, stated, **"Replace nut and perform E.O. 8-55-10-01."**

Log entries by mechanic

- September 29th (Monday) - the graveyard-shift lead mechanic made several entries in the graveyard-shift turnover plan, including
- *"continue parts ordering (PANIC),"*
- *"need copy of E.O. 8-55-10-01 for horiz stab acme screw and nut excessive end play,"* and
- *"... [scheduled] departure looks doubtful."*

Measuring nut thread wear - using a "restraining fixture"



To allow operators to monitor acme nut wear without removing the jackscrew assembly from the airplane, Douglas developed the on-wing end play check procedure. The procedure calls for pulling down on the horizontal stabilizer by applying a specified amount of torque to a tool known as a restraining fixture to change the load on the acme screw from tension to compression

Fixture manufactured in-house

- Up until the time of the accident, Alaska Airlines had only one restraining fixture in its inventory. The fixture was manufactured in-house...
- During several of these tests, the in-house restraining fixtures yielded lower end play measurements ...



Two Alaska Airlines-fabricated restraining fixtures and three Boeing manufactured fixtures

Grease type changes

- In 1996, Alaska Airlines asked McDonnell Douglas if a new grease could be used in place of the original in order to standardize and reduce the number of greases used by the airline.
- laboratory testing [...] somewhat less resistant to water wash-out
- McDonnell Douglas offered a "no technical objection"
- A quid pro quo: Alaska Airlines to return data obtained from in-service aircraft on wear and tear
- (no data returned)

Large margins of safety

- the normal flight load in the screw and nut unit is in the neighborhood of 4,000 or 5,000 pounds
- When the acme nut is new, the strength of the threads is over **15 times** in excess of design loads.
- worn to an end play reading of 0.040" (removal threshold) remains **10 times** stronger
- Taking the end play reading to 0.080", or **twice the removal threshold**, still leaves us with an installation **5 times** stronger than the maximum design loads.

Lubrication maintenance access



Photograph showing maintenance on the horizontal stabilizer of a Northwest Airlines MD-83 aircraft. An American Airlines aircraft is in the background

Recommendation: Increase the size of the access panel to accomplish the lubrication procedures.

Alaska Airlines, maintenance and operations

in 2000 (post-accident !)

- Lack of Management Personnel:
 - Director of Maintenance position has been vacant for nearly two years.
 - Director of Operations position is currently vacant.
 - The Director of Safety is also the Director of Quality Control and Training.
- Maintenance Program:
 - General Maintenance Manual (GMM) does not reflect the procedures that the company is actually using
 - Items are being deferred without using the approved [minimum equipment list], resulting in items not being repaired for long periods of time.

FAA oversight break-down

- ...widespread significant deficiencies that the FAA should have identified earlier.
- ... FAA's surveillance was ineffective before the accident ..[..].. inadequate for at least a year before the accident.
- the replacement of the [Program Tracking and Reporting System \(PTRS\)](#) of oversight at Alaska Airlines with the [Air Transportation Oversight System \(ATOS\)](#) in October 1998 resulted in "a terrible transition" that drastically reduced the amount of time inspectors had for actual surveillance activities.
- "nobody was out there looking at the carrier."

Recap – Insidious erosion of safety over time

- lubrication interval extended
- wear check interval extended
- replacement threshold limits open for interpretation
- tool for wear measurement made in-house
- grease type changes (no monitoring, no records kept)
- items not being repaired for long periods of time
- (intensification of aircraft usage)
(intensification of maintenance work)
- Organizational issues
 - Director of Maintenance position vacant for nearly two years
 - Director of Operations position vacant.
 - The Director of Safety is also the Director of Quality Control
- Breakdown of regulatory oversight

Characteristics of drift

- Each deviation made local sense, and was only an increment away from the previously established norm.
- No rules were violated, no laws broken.
- The oversight regulatory agency concurred with the changes.
- These were normal people doing normal work

Sources

- NTSB (2002) *Aircraft Accident Report. Loss of Control and Impact with Pacific Ocean. Alaska Airlines Flight 261. McDonnell Douglas MD-83, N963AS. About 2.7 Miles North of Anacapa Island, California. January 31, 2000.* National Transportation Safety Board NTSB/AAR-02/01 PB2002-910402 Notation 7263E Adopted December 30, 2002
- Dekker S (2005) *Ten questions about human error.* Taylor and Francis
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- <http://lessons.air.mmac.faa.gov/l2/>
- some pictures from Wikipedia